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CW Operation of a GaAs Injection Laser

Stimulated emission of radiation from forward-biased GaAs diodes was recently observed in several laboratories.[1,2] The observations reported were made with short pulses (< 20 μsec) and a low duty cycle at 77°K. In this Letter continuous stimulated emission is reported.

The structure used is a rectangular parallelepiped with dimensions 100 $\mu \times 120$ $\mu \times 450$ μ similar to the ones in which directionality effects have been observed.[3,4] The *p-n* junction is parallel to the long dimensions of the crystal and is about in the middle of the unit.

Continuous stimulated emission was achieved with the diode immersed in liquid helium II. The bath temperature varied between 1.95° and 2.0°K throughout the runs, higher input powers producing small but observable temperature rises ($\approx$0.03°K). With a direct current flowing through the unit, operation was maintained as long as the liquid helium lasted (more than one-half hour) for more than ten runs. The stimulated emission was not observed for bath temperatures above 2.10°K.

Figure 1 is a photograph of the recorder traces of the spectrum observed from the broad side of the unit at several currents. The broad background, which has a full width at half maximum intensity of 75 A, is the spontaneous emission.

At 38 ma, which is below the threshold, only this spontaneous emission is observed. At 40 ma a prominent narrow stimulated emission line appears at 8383 A. (For Fig. 1 the slits were opened to display both the background and the narrow emission on the same scale.) With increasing current, the stimulated emission at first increases, more rapidly than the background, up to about 70 ma, at which point it starts to decrease. By 85 ma it has disappeared and only the spontaneous emission remains. This quenching is due to heating of the diode as evidenced by the shift of the 85 ma curve to longer wavelengths.

Comparisons of the respective areas under the traces for the narrow peak and the background indicate that

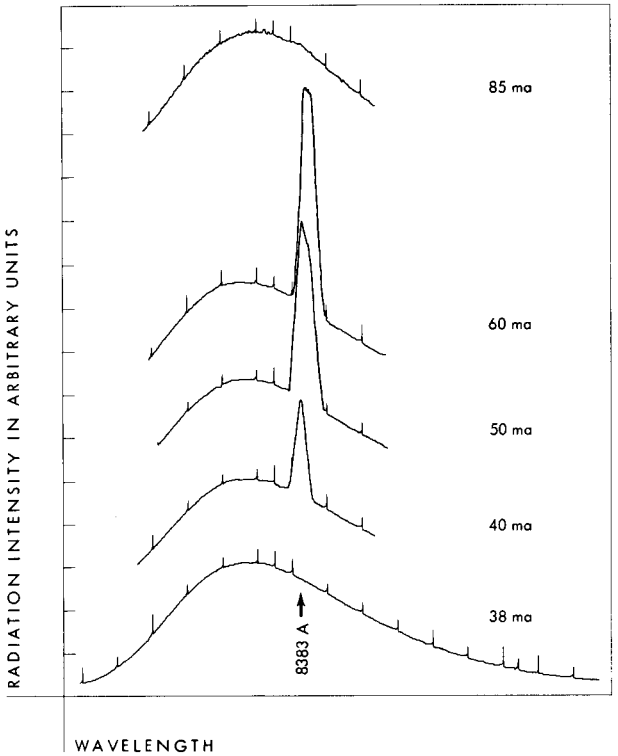

Figure 1 **Recorder traces of the light output spectrum of a cw laser at 1.95° K.**
The light is observed out the long side of the unit in the plane of the junction. There is 11.25 A between markers with an extra marker every ten. The zero for the 38 ma is at the bottom of the chart and each successive curve is displaced upward by 2 divisions from the one below except for the 85 ma curve, which is displaced from the 60 ma curve by 5 divisions. The broad background is the spontaneous emission. The sharp spike is the stimulated emission. The 7.5 A spectral slit width determines the width of the stimulated emission. The area of the junction is 5.4×10^{-4} cm^2.

the maximum fraction of stimulated to total output for this diode is about 9.3% from the end and 10.1% from the side. Thus there is a slight directionality. However observations of the diode with an infrared image converter showed no evidence of a highly directional output. The total output in any direction is proportional to the current for currents up to 70 ma. The output then tends to saturate. The voltage across the diode with 50 ma flowing is 1.55 v. (This compares with the value of the energy gap in pure material of 1.52 ev).[5] The dynamic resistance at this bias is 1.3 ohms.

Figure 2 shows some traces of the stimulated emission with smaller spectral slit width. The width is instrument limited and is less than 1 A. Six modes, or peaks, have been observed, all of them between 8380 and 8392 A. Furthermore, there is a tendency for the emission to jump from one mode to another, of longer wavelength, as the current is increased. In some instances, these jumps occur at higher currents with increasing current than with decreasing current.

Studies of a number of diodes have shown that perfection of the structure is an important factor in cw operation. Further investigations along these lines are planned.

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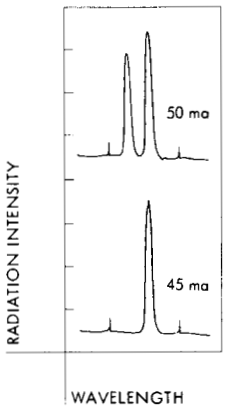
Figure 2 **Recorder traces of the region of the stimulated emission with higher resolution.** *The spectral slit width determines width of the peaks. The two markers are separated by 11.25 A.*



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